Vol. 51, No. 2, pp 110-116, 2023
Indian Journal of Soil Conservation
https://iaswc.com/ijsc-2023.html

Effect of Bakkikayam regulator on groundwater resources using visual MODFLOW - A case study

S. Sajeena[1,*], N.C. Smegha[1] and V.M. Abdul Hakkim[2]

Kelappaji College of Agricultural Engineering and Technology, Tavanur, Kerala Agricultural University, Kerala.

**Corresponding author:*
E-mail: sajeena.s@kau.in (S. Sajeena)

ARTICLE INFO

doi: 10.59797/ijsc.v51.i2.126

Article history:
Received : December, 2021
Revised : August, 2022
Accepted : August, 2022

Key words:
Hydraulic conductivity
Storage coefficient
Transient state calibration
Validation
Prediction
Visual MODFLOW

ABSTRACT

Groundwater resources modeling studies were conducted at the ayacut areas of Bakkikayam regulator situated across the Kadalundi river Pandikasala, Vengara, Malappuram district, Kerala using visual MODFLOW. This study intended to monitor the groundwater behavior in the ayacut regions of Bakkikayam regulator. The conceptual model for the study area was developed using the base map, well logs at 6 sites and the data collected by conducting a geophysical survey of the study area. The aquifer condition of the year 2005 was assumed as the initial condition for a steady state. The transient state calibration of the model was done with eight years of data from 2005 to 2012. The calibrated model was validated with seven years of data from 2013 to 2019. After the validation process, the model was used for predicting the groundwater table for the next five years by increasing the recharge rate by 10, 20 and 30% of the recharge rate of the validation period (2019). By comparing the water table contour map obtained from the validated model before and after the implementation of the Bakkikayam regulator, it could be seen that there was a decline of 3 to 4 m water table on the downstream side of the regulator. An increase in the water table of 2 m was observed during the predicted period due to a 20% increase in the groundwater recharge rate. Beyond that, there was no significant change in the water table, and remained more or less constant. This is because the topography of the downstream area of the Bakkikayam regulator, especially parts of Nannambra and Tirurangadi Panchayaths, comes under low land. The groundwater flow from this area is towards the river and from where water drains into the Arabian sea. This necessitates obstructions to check river flow or any other downstream water conservation measures.

1. INTRODUCTION

Bakkikayam regulator is constructed across the Kadalundi river at Pandikasala in Vengara Panchayth of Malappuram district, Kerala. The main intention of the regulator is to store and conserve water for drinking and agriculture purposes in nearby areas. The regulator is beneficial for the upstream side of the regulator. At the same time, it creates acute water shortage on the downstream side for the paddy cultivation of around 950 acres during its critical stages in Nannambra Panchayat, known as Kuttanad of Malappuram. This led to a massive dispute between upstream and downstream farmers and authorities regarding closing regulators during the summer months. During the critical stages of paddy, crops on the downstream side require sufficient water for crop development; otherwise, complete failure of crops can happen. Hence, it was necessary to conduct a study on the effect of the Bakkikayam regulator on the groundwater flow. Visual MODFLOW software ver 2.8.1, developed by Waterloo Hydrogeologic Inc., was used for the groundwater flow modeling of the study area. This study intended to monitor the groundwater behavior in the ayacut regions of Bakkikayam regulator.

2. MATERIALS AND METHODS

The study area selected for the study was ayacut area of Bakkikayam regulator of about 290 km^2 lies between 11º3'33" to 11º4'1"N latitudes and 76º2'1" to 75º53'3"E longitudes. The location map of the study area is shown in Fig. 1. The ayacut area of the Bakkikayam regulator is spread through fifteen panchayaths *viz.,* Vengara, Kannamangalam, Edarikode, Oorakam, Othukkungal, Parappur, Kottakkal, Perumannaklari, and A.R. Nagarpanchayts in upstream side and Nannambra, Thennala, Munniyur,

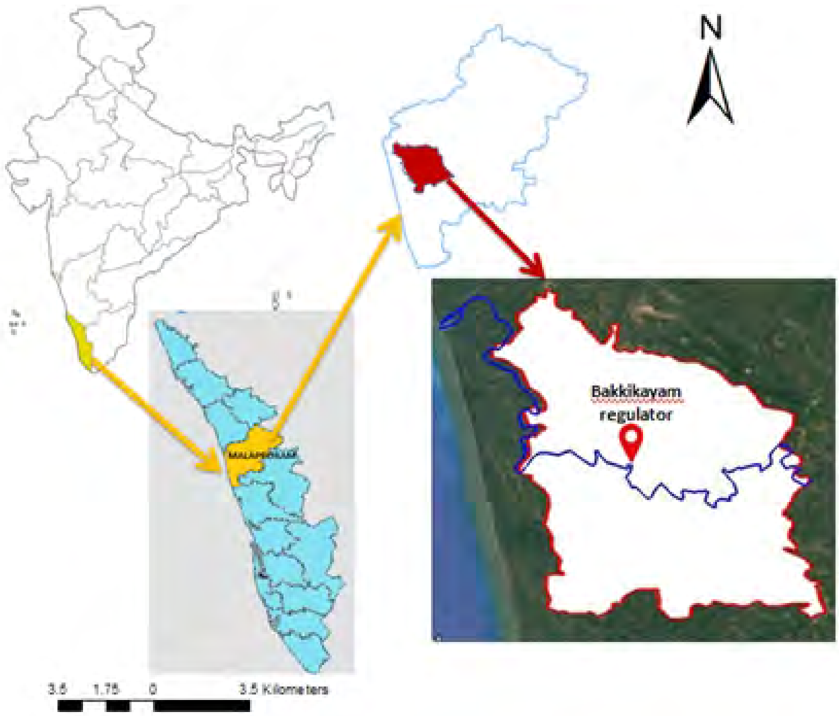

Fig. 1. Location map of the study area

Thenhipalam, Peruvallur and Thirurangadi panchayaths in downstream side of the regulator.

A groundwater model was developed for the study using visual MODFLOW software (2.8.1) (Prasad *et al.,* 2007; Gaghik *et al.,* 2019). A base map was prepared using Google Earth and Arc-GIS (Arc Map 10.4) and imported in to the model in bmp format. The conceptual model for the study area was developed using the base map, well logs at 6 sites, and the data collected by conducting a geophysical survey of the study area. After the development of the conceptual model, the study area was discretized by dividing it into 50 rows and 50 columns with a grid spacing of 530 m × 520 m throughout the area. Thus, the study area was discretized into 2500 cells and the cells outside the boundary of the study area were marked inactive. Field data such as pumping well and observation well data were used as input of visual MODFLOW to simulate real field conditions (Sajeena and Kurien, 2019; Gilsha *et al.,* 2022). Four major pumping wells of Kerala Water Authority were selected for the study. Data collected from six observation wells of the Groundwater Department including four dug wells and two bore wells were used for modeling the real groundwater conditions. The lithology of the area, aquifer properties and soil properties were used to replicate the real conditions of the study area in the model. Hydro-geological parameters, *viz.,* hydraulic conductivity, specific storage, porosity, and specific yield and boundary conditions of the domain, such as constant head, rivers, recharge, and evapotranspiration, were used as input.

The aquifer condition of the year 2005 was assumed as the initial condition for a steady state. The hydraulic conductivity values, groundwater levels, and boundary conditions from the steady state calibration were used as initial transient calibration conditions. The transient state calibration of the model was done with eight years of data from 2005 to 2012. The storage coefficient was varied interactively until a reasonably good match was obtained between the observed and computed groundwater heads. The calibrated model was validated with seven years of data from 2013 to 2019. After the validation process, the model was used for predicting the ground water table for the next five years by increasing the recharge rate by 10, 20 and 30% of the recharge rate of the validation period (2019).

3. RESULTS AND DISCUSSION

Steady State Calibration

The study model was calibrated for a steady-state conditions with the aquifer condition of 2005 as the initial condition of the study area. The steady state model calibration was done by minimizing the difference between the computed and the observed water level for each observation well. The hydraulic conductivity values of the aquifers varied iteratively so that the root mean square (RMS) error could be kept at less than 10 m. The scatter plot of computed *vs.* the observed head for 6 selected observation wells are shown in Fig. 2. From the figure, it could be seen that there was a very good match between the calculated and observed water levels in most of the wells.

Transient State Calibration

The hydraulic conductivity, specific storage and yield values of three layers, water levels, boundary conditions, initial head values, recharge and evaporation data were used for transient state calibration. The transient state calibration was done for the period from the year 2005 to 2012 (2992 days). The hydraulic conductivity and storage values were varied iteratively to obtain a reasonably good match between observed and calculated values.

The graph of calculated head *vs.* Observed head for the 31[st] day is shown in Fig. 3. From the scatter plot for computed *vs.* observed head for the observation wells, it can be seen that there is a good match between the calculated and observed heads in most of the wells in steady-state as well as transient state calibration at a 95% confidence level.

The groundwater contour map after the calibration is shown in Fig. 4. From the figure, it could be concluded that the water table elevation at the coastal region was very low, ranging from 10 to 16 m. while major portion of the study area has the same elevation ranging from 10 m (dark blue) to 22 m (bluish green). Some pockets of Oorakam and Kottakkal were found to have high water tables ranging from 43 to 50 m which may be due to the area's high elevation. Water table elevation of some part of Parappur, Kannamanagalam, and Edarikkode ranged from 25 to 32 m which is justified with the result of Sajeena and Kurien, 2015. This result correlates with the results obtained from the VES studies conducted in the study area.

Validation

The calibrated model was then validated with the ground-

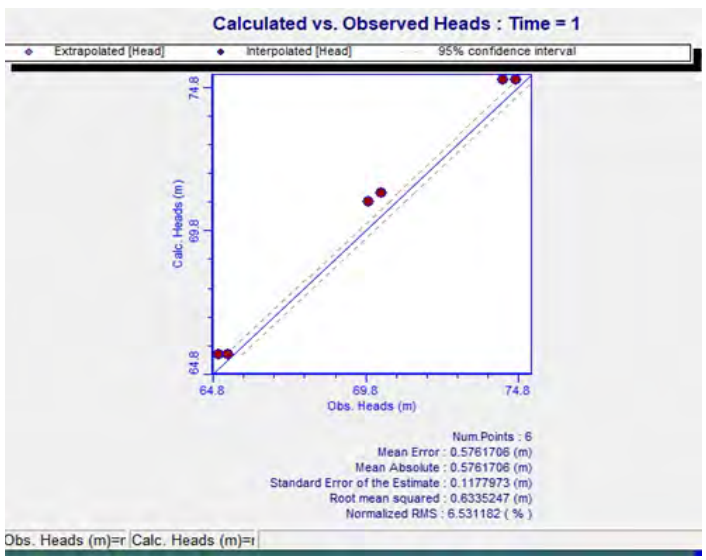

Fig. 2. Model computed *vs.* observed water level of the year 2005 (steady-state)

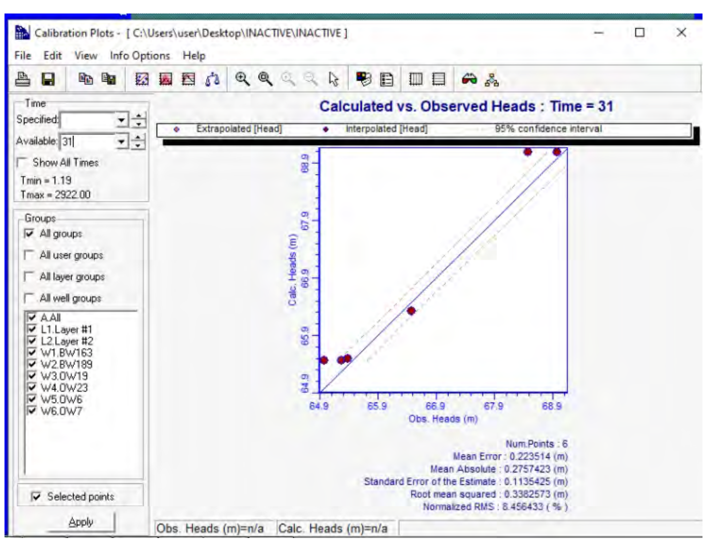

Fig. 3. Model computed *vs.* observed water level of the year 2005 (Transient state)

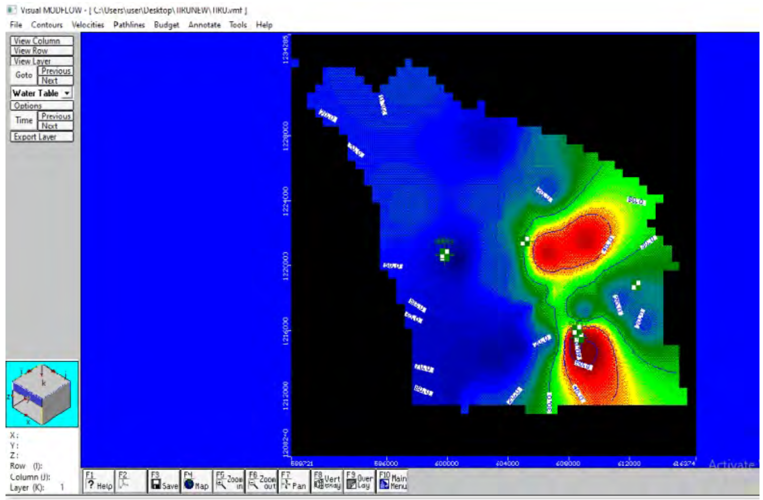

Fig. 4. Computed water table contour map after calibration

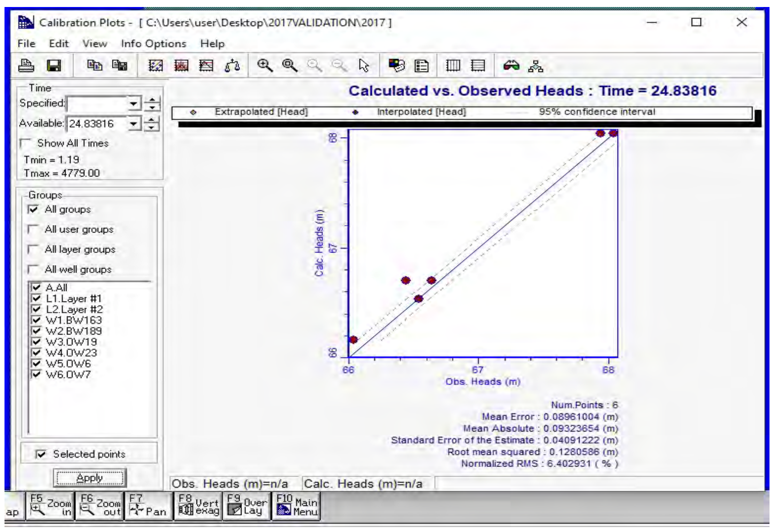

Fig. 5. Model computed *vs.* observed water level after validation up to 2017 (24 Days)

water level data collected from 2013 to 2017 (4748 days) and upto 2019 (5478 days) for analyzing the impact of the Bakkikayam regulator, since the implementation of the regulator was done in 2018. The influence of the Bakkikayam regulator on groundwater level can also be studied using the model.

The scatter plot of calculated *vs.* Observed heads after running the model up to the year 2017 are shown in the Fig. 5, and the study's corresponding groundwater contour map is shown in Fig. 6. The validated values of observed and calculated heads of observation wells are given in Table 1.

Fig. 7 illustrates the groundwater contour map of the study area after running the model upto the year 2019 (5478 days) to analyze the change in the groundwater table after the implementation of the Bakkikkayam regulator. This groundwater contour map was compared with the water table contour map obtained after validation (4748 days), and it could be seen that the light blue color changed to green color, which indicates that there was a decline in the water table about 3 to 4 m in the downstream side of the regulator.

Fig. 8 shows the hydrographs of computed and observed water levels for selected observations wells after validation. The computed well hydrographs for dug wells at Tirurangadi (OW6), vengara (OW 19), Othukkunmgal (OW 23), and bore well at Kottakkal (BW 163) showed a good correlation with observed values of head.

Prediction

In order to analyze the solution to water scarcity during summer months in the downstream area, the validated model was used to predict the groundwater scenario for the coming years by assuming that recharge of the study area will be increased by 10, 20, and 30% of the recharge rate of the validated period (2019) in the entire study area.

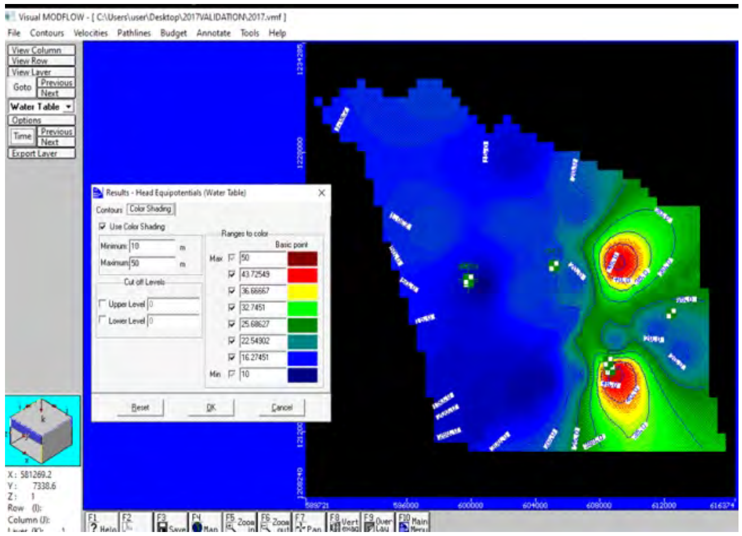

Fig. 6. Groundwater table contour map of the study area after validation

Table: 1
Validated values of observed and calculated heads (from MSL) of observation wells

S.No.	Well name	Observed head (m)	Calculated head (m)	RMSE value
1.	BW 163	67.49	67.90	0.4092
2.	BW 189	68.40	68.12	0.2835
3.	OW6	68.00	68.12	0.1164
4.	OW 7	67.65	67.90	0.2492
5.	OW 19	66.90	66.94	0.0433
6.	OW 23	67.00	67.27	0.2937

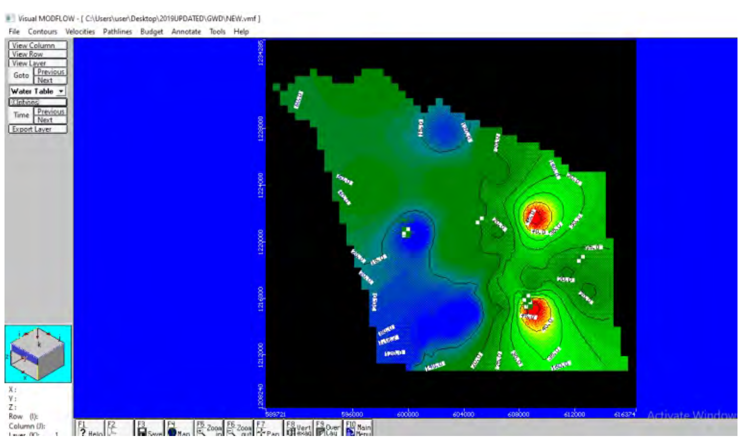

Fig. 7. Water table contour map after running upto 2019

Predicted water table contour maps of the study area by increasing the recharge rate by 10, 20 and 30% are shown in Fig. 9. From the figure; it could be observed that there is an increase of 2 m water table up to the 20% increase of groundwater recharge. After that, there was no significant change in the water table, and remained more or less constant. This is because of the topography of the down-stream area of the Bakkikayam regulator especially Nannambra and Tirurangadi Panchayaths. Most of these Panchayaths are under low land area and the ground water flow is towards the river from where water drains into Arabian sea, unless there are any obstructions to check the flow or any other water conservation measures at the estuary.

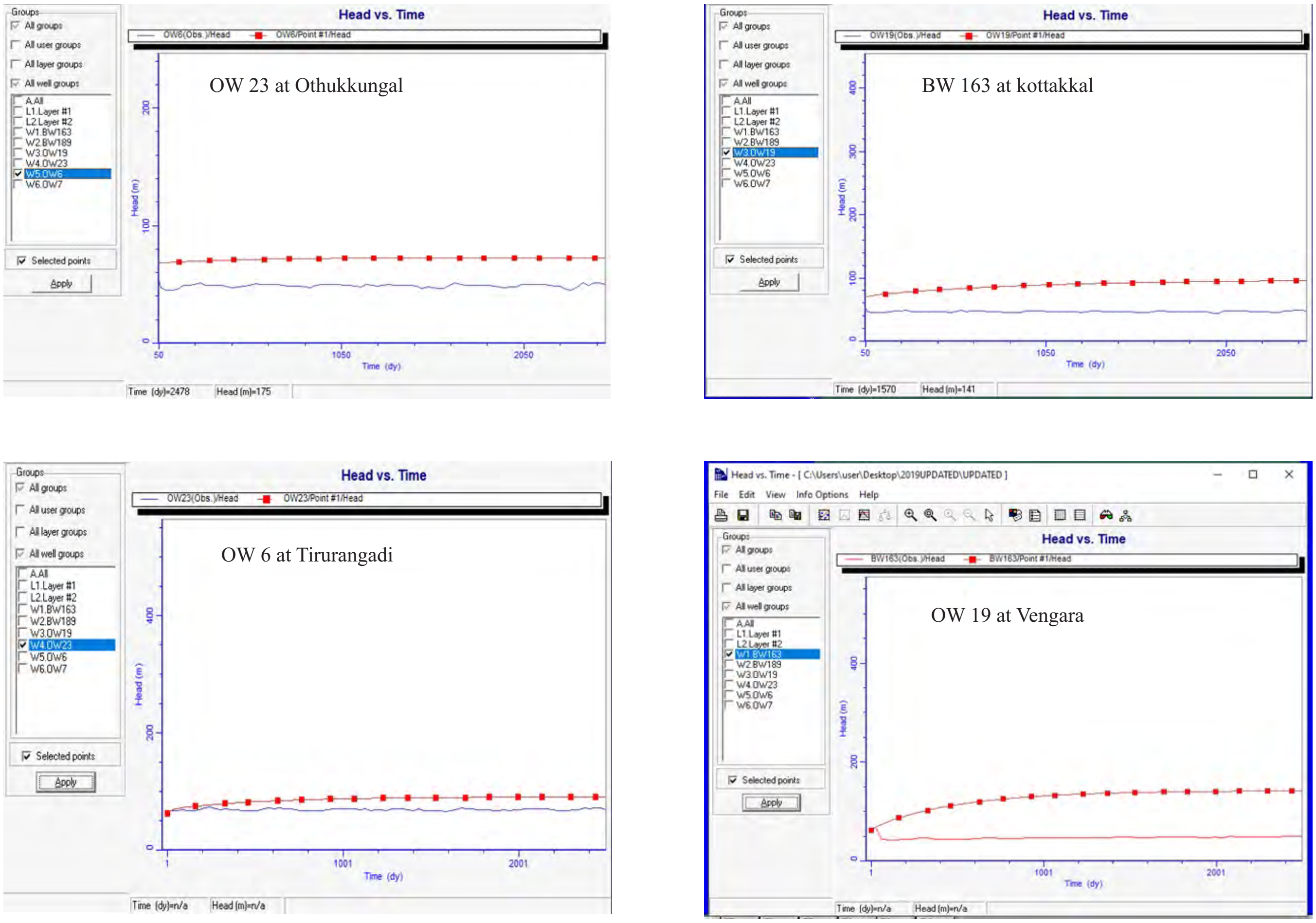

Fig. 8. Computed and observed groundwater level hydrographs for the selected observation wells after validation

4. CONCLUSIONS

From VES data interpretation using IPI2WIN software, it could be concluded that most of the study area showed H, KH, and HK-type sounding curves indicating the presence of good to moderate quality groundwater (Rajkumar *et al.,* 2019. From these studies, it could be concluded that, the top soil of the study area is either laterite soil or hydromorphic soil of thickness 0.75 to 4 m, followed by laterites with varying hardness to a depth of 4 m to 17 m. Lithomargic clay of thickness less than 2 m is seen below the laterites in some places. These layers are overlying weathered rock of 2 m to 14 m thickness followed by hard rock with or without fractures. Major aquifer formations in the study area are identified as laterite, clay and weathered rock.

By comparing the water table contour map obtained from the validated model before and after the implementation of the Bakkikayam regulator, it could be seen that the light blue color changed to green color, which indicated that there was a decline of 3 m to 4 m water table in the downstream side of the regulator.

The validated model is used to predict the water table contour maps of the study area for the next five years by increasing the recharge rate by 10, 20 and 30% of the recharge rate of the validated period (2019). From this study, it could be observed that there is a significant change in the water table up to an increase of 20% in groundwater recharge, around a 2 m increase of water table in a major part of the downstream area. Beyond the 20% increase in recharge, there was no significant change in the water table, and it remained more or less constant. This is because of the topography of the downstream area of the Bakkikayam regulator especially Nannambra and Tirurangadi Panchayaths, part of these Panchayaths are under low land area. The groundwater flow from this area is towards the river from where water drains into Arabian Sea. This necessitates obstructions to check river flow or any other downstream water conservation measures.

ACKNOWLEDGEMENTS

Authors are thankful to Kerala Agricultural University and Kelappaji College of Agricultural Engineering and

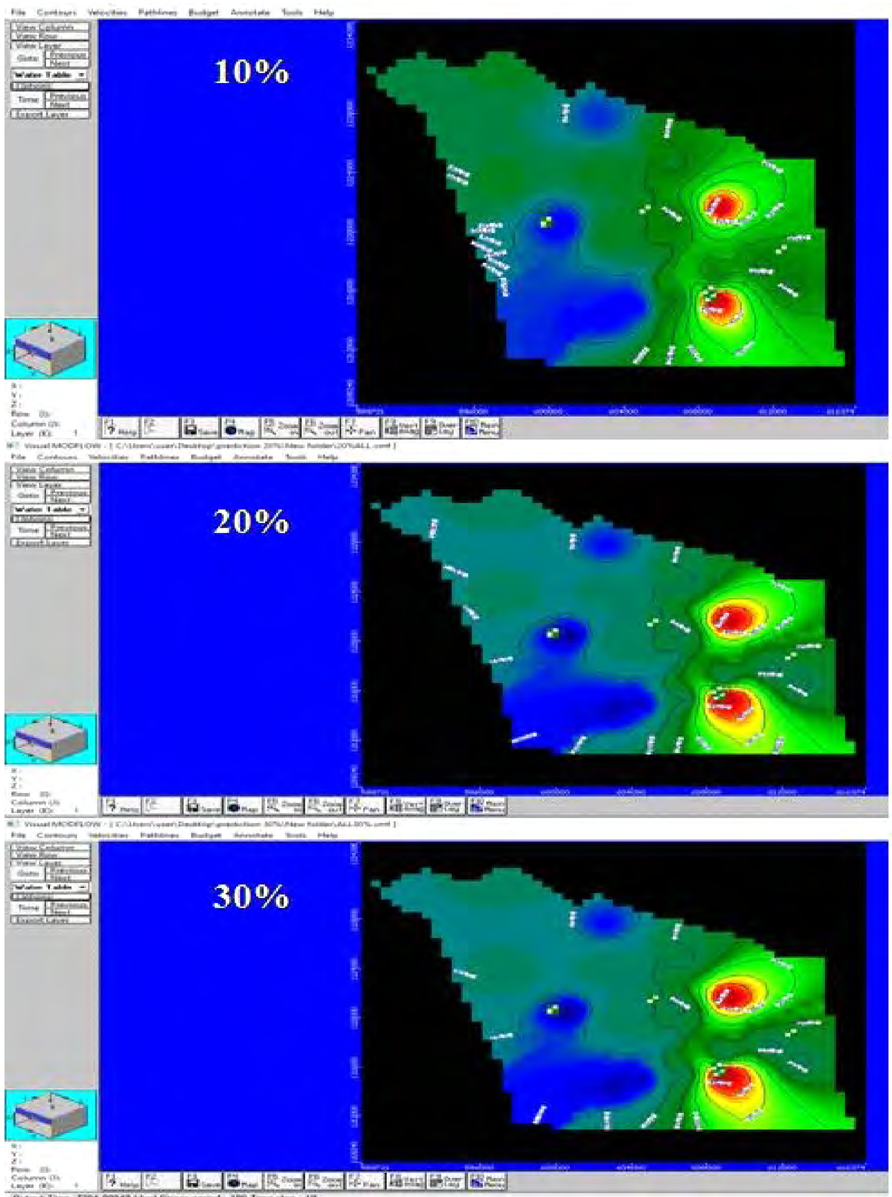

Fig. 9. Predicted water table contour map of the study area by increasing recharge rate 10, 20, and 30%

Technology, Tavanur for sanctioning the research project and providing all financial assistance and also wish to express their gratitude to Groundwater Department, Malappuram, Govt. of Kerala and CWRDM, Kozhikode for their assistance in field investigations, providing information, field data, and helpful discussions.

REFERENCES

Gaghik, H., Pascal, P., Yann L.T., Sandile M., Rianto, V.A. 2019. Mapping spatial distribution of soil properties using electrical resistivity on a long-term sugarcane trial in South Africa. *Geoderma.* 349: 56-67.

Gilsha, B.E.B., Rema, K.P., Sajeena, S. and Sasikala, D. 2022. Simulation of groundwater flow using visual MODFLOW: A case study for the command area of Chalakudy river diversion scheme. *Indian J. Soil Cons.,* 50(1): 29-37.

Prasad, N.N.B., Shivaraj, P.V. and Jagatheesan, M.S. 2007. Evaluation of groundwater development prospects in Kadalundi river basin. *J. Geol. Soc. India*. 69: 1103-1110.

Rajkumar, S., Srinivas, Y., Nithya, C.N. Arunbose, S. 2019. Groundwater quality and vertical electrical sounding data of the Valliyar river basin, south west coast of Tamil Nadu, India. *Data Brief.,* 24: 103919.

Sajeena, S. and Kurien, E.K. 2019. Studies on groundwater resources using visual MODFLOW - A case study of Kadalundi river basin, Malappuram, Kerala. *Indian J. Soil Cons.,* 47(1): 21-29.

Sajeena, S. and Kurien, E.K. 2015. Application of geophysical techniques for groundwater investigation - A case study of Kadalundi river basin, Malappuram, Kerala. *J. Trends Biosci.,* 8(16): 4238-4248.